OPTIMIZATION OF THE CLARENCE CREEK WATER TREATMENT PLANT FOR CONTROL OF TRIHALOMETHANES

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Optimization of the

Clarence Creek

Water Treatment Plant
for Control of Trihalomethanes

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EXECUTIVE SUMMARY

BACKGROUND

The two main objectives of the study are:

1. Improvement of the water treatment plant performance to meet the new Ontario Drinking Water Objectives (ODWO) THMs guideline without compromising disinfection, to achieve a filter effluent turbidity of 0.1 NTU, and to meet the aluminum operational guideline of 100 µg/L.

2. Sustaining long-term performance through skills transfer to plant operating staff and recommendations for plant upgrades where required.

The optimization study was funded by the Ontario Ministry of Environment (MOE), and is a cooperative public/private project between the MOE and RAL Engineering Ltd. By optimizing the performance of their existing facilities, municipalities should be capable of producing water that meets the new THMs objective without requiring costly upgrades.

Trihalomethanes (THMs) are by-products created when the chlorine used in the disinfection process reacts with naturally occurring organics. Trihalomethanes are suspected of increasing the risk of cancer following long term exposure. The Ontario government has lowered the guideline from a maximum acceptable concentration of 350 µg/L, measured as a single occurrence, to an interim maximum acceptable concentration of 100 µg/L based on a running annual average of four quarterly samples.

The optimization of a water treatment plant consists of evaluating the existing treatment units, conducting laboratory testing to determine the best choice and dosage of the treatment chemicals and making changes to plant operation.

EXISTING CONDITIONS

Clarence Creek is a small community located in Clarence Township south east of Ottawa. Its water supply is obtained from four deep wells. Wells No. 1, 3 and 4 are located near the Landry Street pumphouse, and Well No. 2 is located in the Claude Street filtration plant. The Claude Street filtration plant is supplied from Well No. 2 and is equipped with an Ecodyne treatment plant unit including a mixing chamber, one clarifier and one dual media sand filter. The package plant is approximately 20 years old. The plant is operated on demand based on the level in the elevated tank located in town. The Landry Street pumphouse is supplied from Wells No. 1, 3 and 4. Sodium hypochlorite is added to the well pump header. The pumphouse is operated on demand based on the level in the elevated tank. The Landry Street pumphouse is operated as the main source of water supply since the three wells supply better quality water with respect to colour and THMs formation potential.

PERFORMANCE ASSESSMENT

The Clarence Creek groundwater supply has a relatively high chlorine demand meaning that larger amounts of chlorine are required to provide a persistent chlorine residual concentration in the distribution system. The level of THMs in the treated water in 1996 from the pumphouse on Claude Street (Well No. 2) varied from 33 to 142 µg/L for an average of 97 µg/L. The THMs levels from that well exceeded the Ontario Drinking Water Objective (ODWO) of 100 µg/L in April, June, October and December, 1996. The level of THMs in the treated water from the filtration plant on Landry Street (Wells No. 1, 3 and 4) varied from 1 to 101 µg/L for an average of 17 µg/L. The THMs level in the distribution system varied from 1 to 120 µg/L.

The turbidity in the treated water from Wells No. 1, 3 and 4 varied from 0.5 to 2.1 NTU for an average of 1.0 NTU. The turbidity levels in the treated water from Well No. 2 varied from 0.4 to 2.7 NTU for an average of 0.9 NTU. This is below the ODWO of 1 NTU and above the objective of this study which was set to 0.1 NTU for protection against pathogen microorganisms.

The colour level in Well No. 2 is high with an average of 42 TCU. The colour in the treated water for that well ranged from 8 to 29 for an average of 23 TCU. The colour in the treated water from the filtration plant (Wells No. 1, 3 and 4) ranged from 6 to 10 for an average of 8 TCU. This is above the MOE guideline of 5 TCU.

CONCLUSIONS

The drinking water for Clarence Creek is supplied by two well fields. Wells No. 1, 3 and 4 are deep wells and provide a good water quality.

The water supply from Well No. 2 located at the end of town has lower quality and contains methane and sulphide gas, and a higher level of colour and organic matter. The THMs levels from Well No. 2 are higher due to the higher colour in the water.

The turbidity in the treated water from Well No. 2 and the turbidity from Wells No. 1, 3 and 4 both meet the ODWO of 1 NTU but exceeds the objective of this study set at 0.1 NTU for protection against pathogen microorganisms. However, the four wells are deep wells therefore, the presence of microorganisms such as cryptosporidium and giardia cysts is unlikely.

RECOMMENDATIONS FOR SYSTEM MODIFICATIONS

The following is a list of recommendations made at the plant.

1. Addition of ammonium sulphate for chloramination at both water source locations.
2. Modifications to well head piping at the Landry Street pumphouse to improve hydraulics.

These recommendations were implemented during the course of the study

COST ESTIMATE FOR IMPLEMENTATION

The implementation of post-chloramination to reduce the level of THMs in the treated water involved the purchase of two 200 litres day tanks and two mixers for the preparation of ammonium sulphate solution for the Claude Street Filtration Plant and Landry Street Pumphouse. This equipment was purchase for a total cost of approximately $2,000, and was assumed by the MOE. The two dosing pumps required for the injection of ammonium sulphate were already available at the pumphouses.

The additional operating cost related to dosing ammonium sulphate could not be estimated accurately since the exact dosage required was not known. However, it is estimated that the additional chemical cost will be small and is well justified considering the benefit of reducing THMs levels in the distribution system.

OPTIMIZATION
of the

CLARENCE CREEK

WATER TREATMENT PLANT
for
CONTROL OF TRIHALOMETHANES

TABLE OF CONTENTS

1.0 BACKGROUND

Trihalomethanes (THMs) are by-products created when the chlorine used in the disinfection process reacts with naturally occurring organics (eg. formed by decay of algae and vegetation) in raw water. Surface water containing high organics also often has high colour levels. The most common forms of trihalomethanes created are chloroform, bromodichloromethane, chlorodibromomethane and bromoform.

The formation of THMs is influenced by several factors:

• Free chlorine concentration	- higher Cl_2	= higher THMs
• Organic content	- higher organic concentration	= higher THMs
• pH	- higher pH	= higher THMs
• Temperature	- higher temperature	= higher THMs
• Time	- normally longer time	= higher THMs

The formation of trihalomethanes is associated with the presence of organics in the water. This is often the case in inland lakes and rivers, which may contain more organics than large clear bodies of water have a greater trihalomethane formation potential, especially during periods of high runoff. It can also occur when groundwater sources draw water from aquifers high in organics.

The reason for adding chlorine to drinking water is to kill bacteria and other microorganisms that could cause numerous illnesses. However chlorine use leads to the presence of trihalomethanes and this is a cause for concern; studies have found an association between high levels of trihalomethanes in chlorinated drinking water, and slight increases in cancer following long term exposure of more than 35 years.

Chlorine has an advantage over other disinfectants in that it persists many hours or for days and provides protection for the entire water distribution system. The benefit to public health of using chlorine as a disinfectant in drinking water far out-weighs the risk to health associated with the low levels of trihalomethanes created as by-products of chlorination.

In order to decrease the health risk from trihalomethanes, the Canadian and Ontario governments have lowered their respective guideline limits from an "anytime" maximum acceptable concentration of 350 μg/L, measured as a single occurrence, to an interim maximum acceptable concentration of 100 μg/L based on a running annual average of four quarterly samples.

Owners of water treatment plants and water distribution systems who provide water for consumption have legal responsibilities which are shared by all suppliers of food or drink. Owners and suppliers must take reasonable measures to ensure the water is fit for safe consumption.

This optimization study is funded by the Ontario Ministry of the Environment (MOE), and is a cooperative public/private project between the MOE and RAL Engineering Ltd. By optimizing the performance of their existing facilities, municipalities such as Clarence Creek should be capable of producing water that meets the new THMs objective, without resorting to costly upgrades. The optimization of a water treatment plant consists of:

- Documentation of existing facility.
- Assessment of the performance of the water supply system.
- Make required changes to plant operation at full-scale to ensure that changes will minimize the formation of THMs, but will not compromise the disinfection requirement.

2.0 OBJECTIVES

The two main objectives of the study are:

1. IMPROVEMENT OF CLARENCE CREEK WATER TREATMENT PLANT PERFORMANCE

- Improve plant performance without major capital/equipment expenditures. Specific water quality objectives are listed below:

  i To comply with the 100 µg/L ODWO for THMs in treated water as a running annual average of 4 quarterly samples. This objective shall be met while ensuring proper removal and/or inactivation of disease-causing microorganisms such as bacteria and viruses, since this remains the most critical aspect of drinking water treatment.

2. SUSTAINING LONG-TERM PERFORMANCE

- Skills transfer to plant operating staff to enable them to effectively control and adjust processes over the long term.

- Documentation of plant conditions with recommendations for up-grades and operational modifications.

3.0 DOCUMENTATION OF EXISTING CONDITIONS

Clarence Creek is a small community located in Clarence Township south east of Ottawa. Its water supply is obtained from four deep wells. Potential contamination of the groundwater by micro-organisms such as giardia and cryptosporidium is therefore not a concern. Wells No. 1, 3 and 4 are located in the Landry Street pumphouse, and Well No. 2 is located in the Claude Street filtration plant. The water supply system services a population of approximately 800 people. The Landry Street well pumphouse and the Claude Street well/filtration plant system are located at the opposite extremities of the distribution system. A 455 m^3 (100,000 Igal) elevated tank is located in town to provide storage and to regulate the pressure.

3.1 CLAUDE STREET FILTRATION PLANT

The Claude Street filtration plant is supplied from Well No. 2. The maximum capacity of the pumphouse is 4.5 L/s, but it is operated at a nominal capacity of 3.8 L/s to avoid gas formation from methane released to the well under low water level conditions. The plant is equipped with an Ecodyne treatment plant unit including a mixing chamber, one clarifier and one dual media sand filter. The package plant is approximately 20 years old. Sodium hypochlorite is added to the mixing chamber at a dosage of 2 mg/L. The injected chlorine provides disinfection and some bleaching of the colour which is present in the well water due to natural organic material.

The Ecodyne unit is operated as a chlorine contact tank (no coagulant is added), and provides a residence time of approximately 45 minutes at nominal pumping capacity. The filter is backwashed every two weeks. The plant is operated on demand based on the level in the elevated tank located in town. A schematic of the Claude Street filtration plant is presented in Figure 3.1.

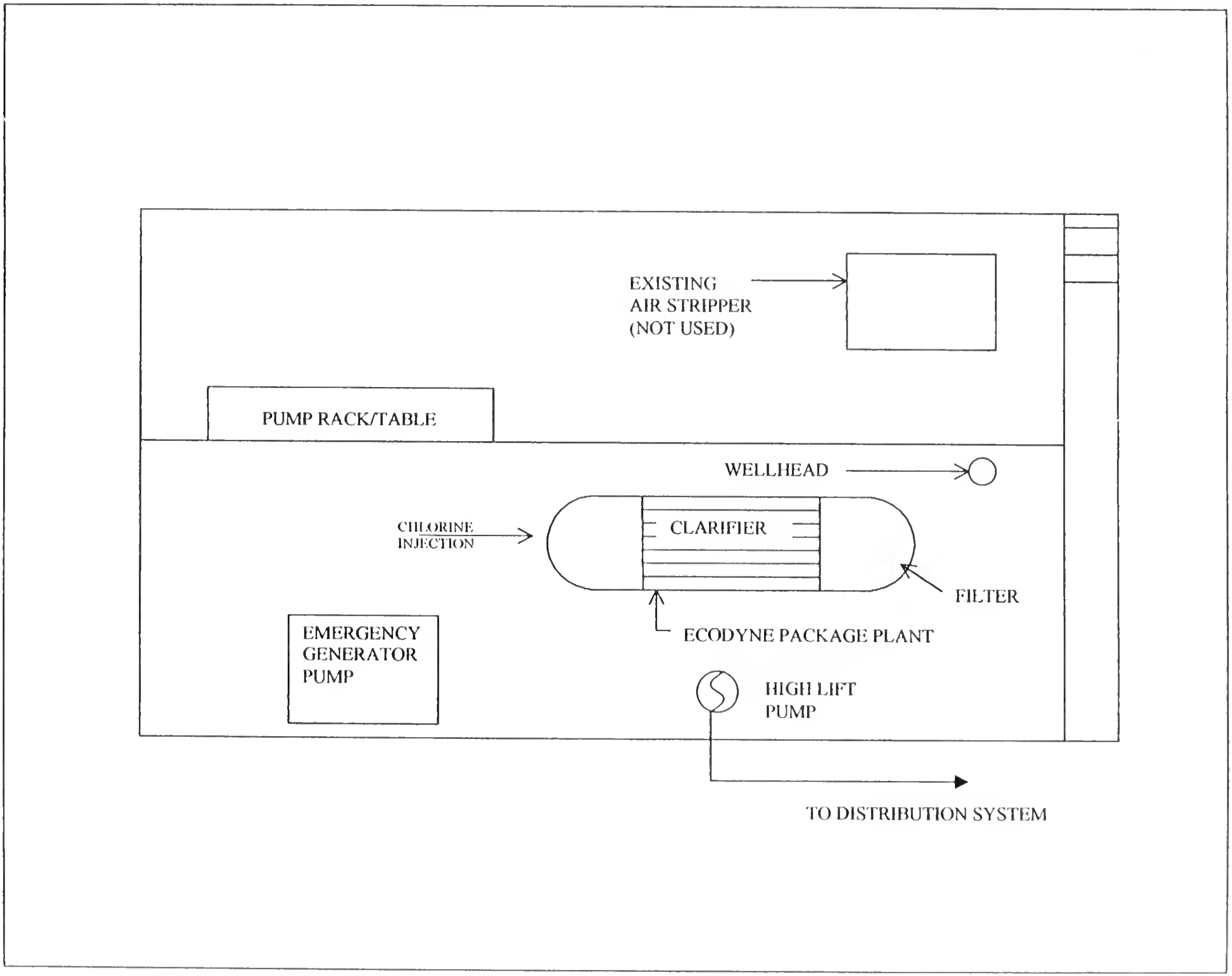

FIGURE 3.1 CLARENCE CREEK WATER TREATMENT PLANT SCHEMATIC – WELL No.2 on CLAUDE STREET

The Claude Street filtration plant consists of:

- ⇒ One deep well (Well No 2).
- ⇒ One Ecodyne package treatment plant.
- ⇒ Sodium hypochlorite injection system for disinfection and to bleach the colour.
- ⇒ One clearwell.

3.2 LANDRY STREET PUMPHOUSE

The Landry Street pumphouse is supplied from Wells No. 1, 3 and 4. The maximum capacity of the wells is summarized as follows:

- Well 1: 0.4 L/s
- Well 3: 1.5 L/s
- Well 4: 1.5 L/s
- Total capacity: 3.4 L/s

Sodium hypochlorite is added to the well pump header. The injected chlorine provides disinfection and some bleaching of the colour present in the well water due to natural organic material. At the beginning of the study, silicate was added as a sequestering agent to reduce red water formation developed for the oxidation of iron after chlorine addition. The pumphouse includes a 0.3 m diameter in-ground pipe to provide chlorine contact time prior to the first customer. The pumphouse is operated on demand based on the level in the elevated tank. The Landry Street pumphouse is operated as the main source of water supply since the three wells supply better quality water with respect to colour and THMs formation potential. A schematic of the Landry Street plant is presented in Figure 3.2.

The Landry Street pumphouse consists of:

- ⇒ Three deep wells (Wells No. 1, 3 and 4).
- ⇒ Sodium hypochlorite injection system for disinfection and to bleach the colour.
- ⇒ Silicate injection system for sequestering iron and manganese.
- ⇒ One large diameter pipe (0.3 m diameter) for chlorine contact time.

The water demands in town are generally:

Average day flow	364 m^3/d (4.2 L/s)
Nominal system capacity	622 m^3/d (7.2 L/s)

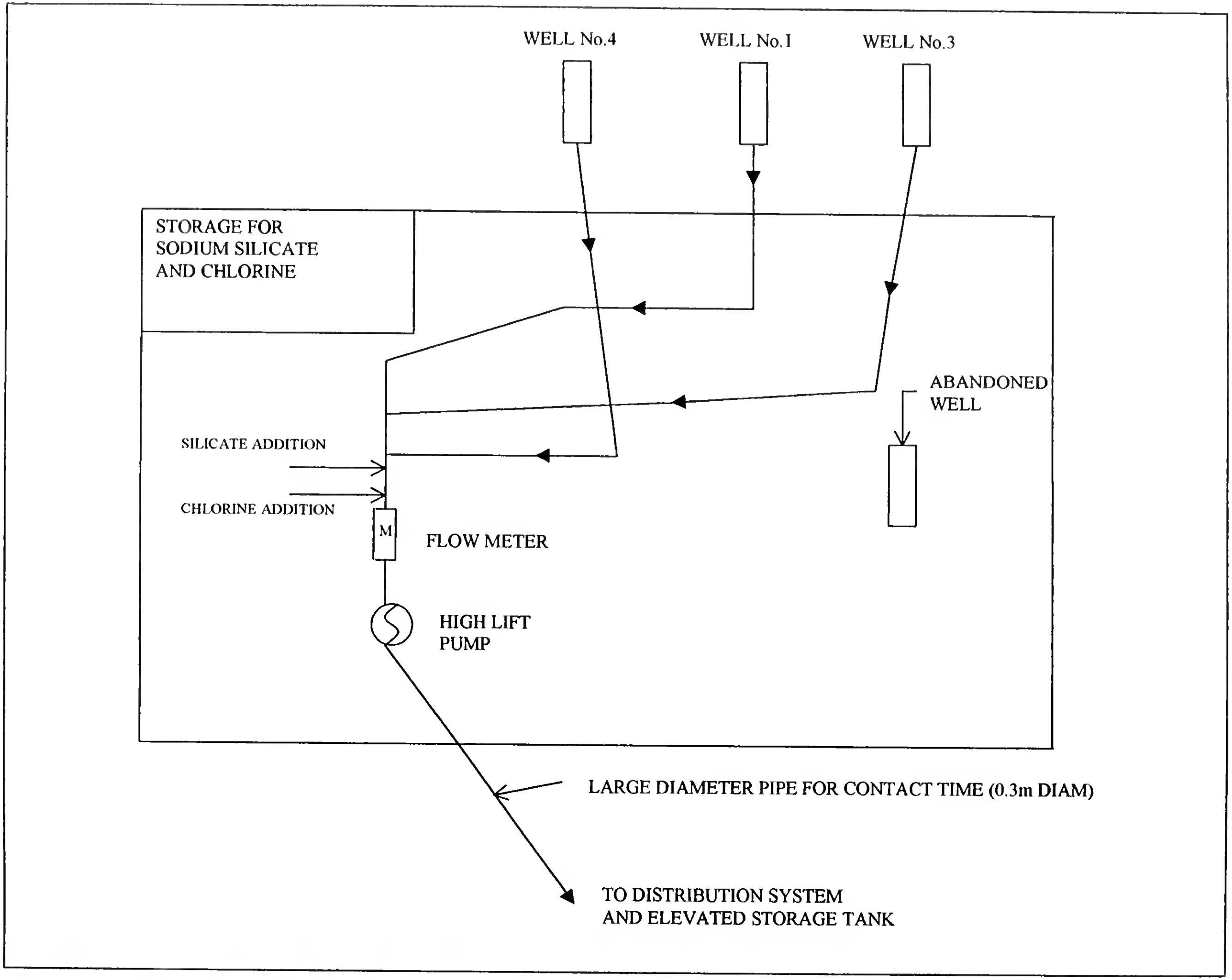

FIGURE 3.2 CLARENCE CREEK PLANT SCHEMATIC – WELLS Nos.1,3 and 4 on LANDRY STREET

3.3 HISTORICAL DATA FOR 1996

A summary of historical data from January to December 1996 is presented in Table 3.1. The table is a summary of concentrations measured for turbidity, colour, pH, aluminum residual, iron, manganese, trihalomethanes (THMs) and haloacetic acids (HAAs) for the raw and the treated water. The range and annual average are summarized below:

Parameters		*Range*	*Average*
Colour:	- Well 1*:	12 TCU	* January data only
	- Well 2:	32 to 53 TCU	42 TCU
	- Well 3*:	10 TCU	
	- Well 4*:	11 TCU	
	- Tr. Water Wells 1,3,4:	6 to 10 TCU	8 TCU
	- Tr. Water Well 2:	8 to 29 TCU	23 TCU
Turbidity:	- Well 1*:	1.6 NTU	* January data only
	- Well 2:	0.6 to 1.1 NTU	0.8 NTU
	- Well 3*:	2.9 NTU	
	- Well 4*:	2.5 NTU	
	- Tr. Water Wells 1,3,4:	0.5 to 2.1 NTU	1.0 NTU
	- Tr. Water Well 2:	0.4 to 2.7 NTU	0.9 NTU
pH:	- Well 1*:	8.2	* January data only
	- Well 2:	7.8 to 8.3	8.1
	- Well 3*:	8.2	
	- Well 4*:	8.4	
	- Tr. Water Wells 1,3,4:	7.9 to 8.3	8.2
	- Tr. Water Well 2:	8.1 to 8.5	8.3
Alkalinity:	- Well 1*:	324 mg/L	* January data only
	- Well 2:	398 to 425 mg/L	412 mg/L
	- Well 3*:	308 mg/L	
	- Well 4*:	342 mg/L	
	- Tr. Water Wells 1,3,4:	322 to 340 mg/L	331 mg/L
	- Tr. Water Well 2:	350 to 422 mg/L	404 mg/L

Parameters		*Range*	*Average*
DOC:	- Well 1*:	2.7 mg/L	* January data only
	- Well 2:	4.3 to 5.6 mg/L	5.0 mg/L
	- Well 3*:	3.5 mg/L	
	- Well 4*:	2.5 mg/L	
	- Tr. Water Wells 1,3,4:	2.2 to 2.7 mg/L	2.5 mg/L
	- Tr. Water Well 2:	2.8 to 5.6 mg/L	4.7 mg/L
Aluminum:	- Well 1*:	3 µg/L	* January data only
	- Well 2:	3 µg/L	
	- Well 3*:	22 µg/L	
	- Well 4*:	35 µg/L	
	- Tr. Water Wells 1,3,4:	2 µg/L	
	- Tr. Water Well 2:	3 to 5 µg/L	4 µg/L
Iron:	- Well 1*:	0.3 mg/L	* January data only
	- Well 2*:	0.1	
	- Well 3*:	0.2 mg/L	
	- Well 4*:	0.3 mg/L	
	- Tr. Water Wells 1,3,4:	0.3 to 0.4 mg/L	0.3 mg/L
	- Tr. Water Well 2*:	0.1 mg/L	
Manganese:	- Well 1*:	0.052 mg/L	
	- Well 2*:	0.045 mg/L	
	- Well 3*:	0.046 mg/L	
	- Well 4*:	0.041 mg/L	
	- Tr. Water Wells 1,3,4:	0.045 to 0.060	0.053 mg/L
	- Tr. Water Well 2:	0.009 to 0.015	0.012 mg/L
THMs:	- Tr. Wat. Wells 1,3,4:	1 to 101	17 µg/L
	- Dist. Syst. Claude St.	2 to 120	52 µg/L
	- Tr. Water Well 2:	33 to 142	97 µg/L
	- Dist. Syst. Landry St.	1 to 91	25 µg/L
HAAs:	- Tr. Wat. Wells 1,3,4:	13 to 64	39 µg/L
	- Dist. Syst. Claude St.	15 to 38	29 µg/L
	- Tr. Water Well 2:	31 to 95	63 µg/L
	- Dist. Syst. Landry St*.	12 µg/L	* November data only

TABLE 3.1 CLARENCE CREEK WATER TREATMENT PLANT
MONTHLY AVERAGE WATER QUALITY RESULTS - 1996
WATER SAMPLES ANALYZED BY THE MOE FOR THE DRINKING WATER SURVEILLANCE PROGRAM (DWSP)

	JAN	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	MINIMUM	MAXIMUM	AVERAGE
TURBIDITY - WELL 1 (NTU)	1.6	-	-	-	-	-	-	-	-	-	-	-	-
TURBIDITY - WELL 2 (NTU)	0.6	-	-	-	-	1.1	-	-	-	-	0.6	1.1	0.8
TURBIDITY - WELL 3 (NTU)	2.9	-	-	-	-	-	-	-	-	-	-	-	-
TURBIDITY - WELL 4 (NTU)	2.5	-	-	-	-	-	-	-	-	-	-	-	-
TURBIDITY - TR. WAT. WELLS 1,3,4 (NTU)	0.6	-	0.8	2.1	0.9	2.1	0.7	-	0.7	0.5	0.5	2.1	1.0
TURBIDITY - TR. WAT. WELL 2 (NTU)	0.4	-	0.7	2.7	0.6	0.6	0.8	-	0.8	0.6	0.4	2.7	0.9
COLOUR - WELL 1 (TCU)	12	-	-	-	-	-	-	-	-	-	-	-	-
COLOUR - WELL 2 (TCU)	53	-	-	-	-	32	-	-	-	-	32	53	42
COLOUR - WELL 3 (TCU)	10	-	-	-	-	-	-	-	-	-	-	-	-
COLOUR - WELL 4 (TCU)	11	-	-	-	-	-	-	-	-	-	-	-	-
COLOUR - TR. WAT. WELLS 1,3,4 (TCU)	7	-	7	8	7	6	8	-	8	10	6	10	8
COLOUR - TR. WAT. WELL 2 (TCU)	26	-	24	29	25	8	21	-	28	26	8	29	23
DOC - WELL 1 (mg/L)	2.7	-	-	-	-	-	-	-	-	-	-	-	-
DOC - WELL 2 (mg/L)	5.6	-	-	-	-	4.3	-	-	-	-	4.3	5.6	5.0
DOC - WELL 3 (mg/L)	3.5	-	-	-	-	-	-	-	-	-	-	-	-
DOC - WELL 4 (mg/L)	2.5	-	-	-	-	-	-	-	-	-	-	-	-
DOC - TR. WAT. WELLS 1,3,4 (mg/L)	2.6	-	2.4	2.4	2.2	2.3	2.4	-	2.7	2.7	2.2	2.7	2.5
DOC - TR. WAT. WELL 2 (mg/L)	5.6	-	4.5	5.6	4.7	2.8	4.4	-	5.2	5.1	2.8	5.6	4.7
pH - WELL 1	8.2	-	-	-	-	-	-	-	-	-	-	-	-
pH - WELL 2	8.3	-	-	-	-	7.8	-	-	-	-	7.8	8.3	8.1
pH - WELL 3	8.2	-	-	-	-	-	-	-	-	-	-	-	-
pH - WELL 4	8.4	-	-	-	-	-	-	-	-	-	-	-	-
pH - TR. WAT. WELLS 1,3,4	8.3	-	7.9	8.2	8.2	8.1	-	-	8.2	8.3	7.9	8.3	8.2
pH - TR. WAT. WELL 2	8.3	-	8.1	8.3	8.3	8.1	-	-	8.4	8.5	8.1	8.5	8.3
ALKALINITY - WELL 1 (mg/L)	324	-	-	-	-	-	-	-	-	-	-	-	-
ALKALINITY - WELL 2 (mg/L)	425	-	-	-	-	398	-	-	-	-	398	425	412
ALKALINITY - WELL 3 (mg/L)	308	-	-	-	-	-	-	-	-	-	-	-	-
ALKALINITY - WELL 4 (mg/L)	342	-	-	-	-	-	-	-	-	-	-	-	-
ALKALINITY - TR. WAT. WELLS 1,3,4 (mg/L)	324	-	322	325	333	334	331	-	338	340	322	340	331
ALKALINITY - TR. WAT. WELL 2 (mg/L)	421	-	403	413	410	350	390	-	422	422	350	422	404
ALUMINUM - WELL 1 (ug/L)	3	-	-	-	-	-	-	-	-	-	-	-	-
ALUMINUM - WELL 2 (ug/L)	3	-	-	-	-	-	-	-	-	-	-	-	-
ALUMINUM - WELL 3 (ug/L)	22	-	-	-	-	-	-	-	-	-	-	-	-
ALUMINUM - WELL 3 (ug/L)	35	-	-	-	-	-	-	-	-	-	-	-	-
ALUMINUM - TR. WAT. WELLS 1,3,4 (ug/L)	2	-	-	-	-	-	-	-	2	-	-	-	-
ALUMINUM - TR. WAT. WELL 2 (ug/L)	3	-	-	-	-	-	-	-	5	-	3	5	4
IRON - WELL 1 (mg/L)	0.3	-	-	-	-	-	-	-	-	-	-	-	-
IRON - WELL 2 (mg/L)	0.1	-	-	-	-	-	-	-	-	-	-	-	-
IRON - WELL 3 (mg/L)	0.2	-	-	-	-	-	-	-	-	-	-	-	-
IRON - WELL 4 (mg/L)	0.3	-	-	-	-	-	-	-	-	-	-	-	-
IRON - TR. WAT. WELLS 1,3,4 (mg/L)	0.3	-	-	-	-	-	-	-	0.4	-	0.3	0.4	0.3
IRON - TR. WAT. WELL 2 (mg/L)	0.1	-	-	-	-	-	-	-	0.1	-	-	-	-
MANGANESE - WELL 1 (mg/L)	0.052	-	-	-	-	-	-	-	-	-	-	-	-
MANGANESE - WELL 2 (mg/L)	0.045	-	-	-	-	-	-	-	-	-	-	-	-
MANGANESE - WELL 3 (mg/L)	0.046	-	-	-	-	-	-	-	-	-	-	-	-
MANGANESE - WELL 4 (mg/L)	0.041	-	-	-	-	-	-	-	-	-	-	-	-
MANGANESE - TR. WAT. WELLS 1,3,4 (mg/L)	0.045	-	-	-	-	-	-	-	0.060	-	0.045	0.060	0.053
MANGANESE - TR. WAT. WELL 2 (mg/L)	0.015	-	-	-	-	-	-	-	0.009	-	0.009	0.015	0.012
THMs - TR. WAT. WELLS 1,3,4 (ug/L)	101	-	13	12	1	9	5	8	6	2	1	101	17
THMs - DIST. SYS. CLAUDE ST. (ug/L)	46	-	10	37	2	23	63	98	74	120	2	120	52
THMs - TR. WAT. WELL 2 (ug/L)	141	123	71	142	95	33	66	113	72	118	33	142	97
THMs - DIST. SYS. LANDRY ST. (ug/L)	-	-	65	1	91	12	3	22	5	2	1	91	25
HAAs - TR. WAT. WELLS 1,3,4 (ug/L)	64	-	-	-	-	-	-	-	13	-	13	64	39
HAAs - DIST. SYS. CLAUDE ST. (ug/L)	38	-	15	-	-	-	-	-	33	-	15	38	29
HAAs - TR. WAT. WELL 2 (ug/L)	95	-	-	-	-	-	-	-	31	-	31	95	63
HAAs - DIST. SYS. LANDRY ST. (ug/L)	-	-	-	-	-	-	-	-	12	-	-	-	-

The Clarence Creek groundwater supply, more specifically Well No 2, has a relatively high chlorine demand meaning that larger amounts of chlorine are required to provide a persistent chlorine residual concentration in the distribution system. Some of the chlorine added for disinfection reacts chemically with the organics present in the water and produces THMs. The level of THMs in the treated water in 1996 from the pumphouse on Claude Street (Well No. 2) varied from 33 to 142 µg/L for an average of 97 µg/L. The THMs levels from that well exceeded the Ontario Drinking Water Objective (ODWO) of 100 µg/L in April, June, October and December, 1996. The level of THMs in the treated water from the filtration plant on Landry Street (Wells No. 1, 3 and 4) varied from 1 to 101 µg/L for an average of 17 µg/L. The THMs level in the distribution system varied from 1 to 120 µg/L.

The water samples taken for THMs analysis in the distribution system were quenched with sodium thiosulfate to remove chlorine residual to stop any further reaction between free chlorine and organics. Quenched water samples taken in the distribution system will maintain the same level of THMs as existed at the time of sampling, thereby representing the quality experienced by the consumer. The water samples taken for THMs analysis at the pumphouses were not quenched.

The levels of organic matter measured by dissolved organic carbon (DOC) analysis are relatively high for the Well No.2. The DOC concentration in Well No.2 varied from 4.3 to 5.6 mg/L for an average of 5.0 mg/L. The average concentration in the treated water from Well No. 2 was 4.7 mg/L. The DOC concentration from Wells No. 1, 3 and 4 was 2.5 mg/L.

The turbidity in the treated water from Wells No. 1, 3 and 4 varied from 0.5 to 2.1 NTU for an average of 1.0 NTU. The turbidity levels in the treated water from Well No. 2 varied from 0.4 to 2.7 NTU for an average of 0.9 NTU. This is below the ODWO of 1 NTU and above the objective of this study which was set to 0.1 NTU for protection against pathogen microorganisms.

The colour level in Well No. 2 is high with an average of 42 TCU. The colour in the treated water for that well ranged from 8 to 29 for an average of 23 TCU. The colour in the treated water is lower than the colour directly from the well. This is due to bleaching from chlorine used for disinfection. The colour in the treated water from the filtration plant (Wells No. 1, 3 and 4) ranged from 6 to 10 for an average of 8 TCU. This is above the MOE guideline of 5 TCU. Colour is an aesthetic and not a health related parameter, but high levels are indicative of the presence of organics which react with chlorine to form THMs.

Historical data for 1996 indicated that the Wells No. 1,3, and 4 have an iron level ranging from 0.3 to 0.4 mg/L, which is slightly above the MOE guideline of 0.3 mg/L. The sampling also indicated that the level of manganese found in these three wells ranges from 0.045 to 0.06 mg/L for an average of 0.053 mg/L. This is above the MOE guideline of 0.05 mg/L. The concentration of iron in Well No. 2 is lower with a level of 0.1 mg/L. The average concentration of manganese in the treated water from Well No. 2 is 0.012 mg/L.

Analysis were performed to evaluate the level of haloacetic acids (HAAs) in the treated water. HAAs are by-products of disinfection from chlorine reacting with humic substances. HAAs are found to be ubiquitous and of concern to human health. Currently, there is no guideline in Ontario regulating the maximum level of HAAs in drinking water. The US Environmental Protection Agency (USEPA) has proposed regulating five major HAAs in the upcoming Disinfectants/Disinfection By-products (D/DBP) Rule – monochloroacetic acid (MCAA), DCAA, TCAA, monobromoacetic acid (MBAA), and dibromoacetic acid (DBAA). In the first stage of the D/DBP Rule, the proposed maximum contaminant level is 60 µg/L for the total concentration of these five HAAs.

Samples were taken for HAAs analysis in the treated water from the pumphouse on Landry Street and from the filtration plant on Claude Street, as well as in the distribution system. The samples taken at the plant and the pumphouse were unquenched and the samples in the distribution system were quenched with ammonium chloride to stop any further formation representing the quality experienced by the consumer. The level of HAAs in the treated water collected at the Landry Street plant ranged from 13 to 64 µg/L, and the samples from the Claude Street filtration plant ranged from 31 to 95 µg/L. HAAs concentrations in the distribution system on Claude Street ranged from 15 to 38 µg/L. One water sample taken from the distribution system on Landry Street in November 1996 indicated a concentration of 12 µg/L. Additional samples would be required to confirm actual HAAs concentration in the treated water.

4.0 CONCLUSIONS

The drinking water for Clarence Creek is supplied by two well fields. Wells No. 1, 3 and 4 are deep wells and provide a good water quality. The THMs level from Wells No. 1,3, and 4 varied from 1 to 101 µg/L. The colour in the treated water from the pumphouse varied from 6 to 10 TCU.

The water supply from Well No. 2 located at the end of town has lower quality and contains methane and sulphide gas, and a higher level of colour and organic matter. The water passes through an Ecodyne package treatment plant with no addition of chemical other than chlorine which is used for disinfection and to oxidize the colour and sulphide gas. The THMs levels from Well No. 2 are higher (33 to 142 µg/L). The colour in the treated water ranges from 8 to 29 TCU for an average of 23 TCU.

Based on the 1996 water quality data, the turbidity in the treated water from Well No. 2 averaged 0.9 NTU, and the average turbidity from Wells No. 1, 3 and 4 was 1.0 NTU. This meets the ODWO of 1 NTU but exceeds the objective of this study set at 0.1 NTU for protection against pathogen microorganisms. However, the four wells are deep wells therefore, the presence of microorganisms such as cryptosporidium and giardia cysts is unlikely. Stricter requirement for particles removal and disinfection is not warrant.

5.0 RECOMMENDATIONS

A new pump manifold was installed at the Landry Street pumphouse (Wells No. 1, 3 and 4) in the fall of 1997 to increase the pumping capacity of the well field and to reduce the need to use the water supply from Well No. 2. This improved the overall quality of the water supply in Clarence Creek. by reducing THMs formation and by helping to maintain a colour level in the distribution system below 15 to 20 TCU.

The recommendation made to further reduce the levels of THMs for the Clarence Creek water supply system is summarized as follows:

- Perform chloramination of the treated water entering the clearwell at the Claude Street Filtration Plant and at the Landry Street Pumphouse.

To avoid creating a mixing zone in the distribution system, it is recommended to perform chloramination from both water supplies to avoid the formation of dichloramines responsible for taste problem. Ammonia combines chemically with chlorine to produce chloramine. Use of chloramine has two consequences relevant to drinking water quality. These are as follows:

1. Chloramine does not react with organics present in the water to form THMs.
2. Chloramine is a less powerful disinfectant than chlorine and care must be taken to ensure this factor does not affect water quality.

Sodium hypochlorite will be added to provide a free chlorine residual of 2 mg/L prior to the addition of ammonium sulphate to maintain a combine chlorine residual or chloramine level leaving the Claude and Landry streets pumphouses of 2 mg/L. The AWWA recommends a minimum residual of 1.0 mg/L of chloramine be maintained in the distribution system to prevent re-growth (AWWA, 1993).

The equipment required to achieve water disinfection through chloramination in place of the existing chlorination for the pumphouses located on Landry and Claude streets is described as follows:

- Installation of a 200 litre capacity solution day tank, one corrosion resistant mixer, and one positive displacement chemical metering pump rated at 10 L/h, with a solution line to the well pump header immediately downstream of the existing sodium hypochlorite solution application point in the pumphouse serving Wells No. 1, 3 and 4.

- Installation of a 200 litre capacity solution day tank, one corrosion resistant mixer, and one positive displacement chemical metering pump rated at 10 L/h, with a solution line to the filter effluent of the existing package water treatment unit (downstream of the existing sodium hypochlorite solution application point located in the mix compartment of the unit), in the filtration plant serving Well No 2.

A copy of the temporary Certificate of Approval (C of A) for the experimental installation as described above is presented in Appendix A. The temporary C of A was valid from August 1997 to September 1998. This condition was included to ensure that the proposed equipment installed and used for the purpose of the proposed experiment was not to become a permanent part of the system unless approved by the MOE Approval Branch.

The following recommendations were made for the Claude Street plant prior to switching to chloramination:

1. Add a new sample point on the filter outlet pipe for ease of control.
2. Install a power supply for the ammonium sulphate feed pump that is interrupted when the well pump shuts down.

The changes recommended for the Landry Street pumphouse are summarized as follows:

1. Stop using silicate for sequestering of iron and manganese to reduce colour formation in the treated water, since it was found to be not necessary (implemented in the fall of 1997).
2. Replumbing of the well water receiver manifold to 150 mm (6 inches) piping for better hydraulics. This recommendation was implemented in the fall of 1997.
3. In replumbing the manifold, a new sample valve should be fitted immediately upstream of the ammonium sulphate injection point to allow for accurate free chlorine sampling and measurement.
4. Separation of 1 to 1.2 metres is advised between the chlorine injection point and the ammonium sulphate injection. A similar distance is also recommended downstream of the ammonium sulphate injection prior to entering the existing large diameter underground pipe. These pipe runs are recommended to help mixing the chlorine first and then the ammonium sulphate solution.

The post-chloramination treatment has proved satisfactory by producing THMs levels in the treated water between 60 to 70 μg/L. It is expected that the THMs concentration will now remain below 100 μg/L throughout the distribution system. Disinfection of the Clarence Creek water supply by performing post-chloramination will be implemented on a permanent basis. Application for a permanent Certificate of Approval will need to be prepared.

Dosage of Ammonium Sulphate

Ammonia can be supplied as a compressed liquefied or saturated solution, a gas form, or in dry compounds. Ammonia gas is toxic and corrosive, and handling the concentrated solution requires refrigeration. Consequently, ammonium sulphate in dry compound is preferred. Ammonium sulphate is a crystalline water soluble salt which is not strongly toxic. When required, the ammonium sulphate solution should be prepared at least weekly. This solution is added to the main water stream at controlled dosage rate.

The procedure recommended for determining the dosage of ammonium sulphate required is as follows:

- Check the concentration of free chlorine residual immediately after injection of sodium hypochlorite.
- Samples from this point must be allowed to stand for approximately 30 minutes in a full closed container before testing with the DR700 analyzer to obtain accurate free chlorine residuals.
- Adjust chlorine feed to give a free chlorine residual of 2 mg/L at this point.
- The concentration of free chlorine residual can then be used to accurately adjust the injection rate of ammonium sulphate to give a combine chlorine residual of 2 mg/L.
- The preparation of the ammonium sulphate solution for a 7 day supply is described in Appendix B.

6.0 COSTS ESTIMATE FOR IMPLEMENTATIONS

The implementation of post-chloramination to reduce the level of THMs in the treated water involved the purchase of two 200 litres day tanks and two mixers for the preparation of ammonium sulphate solution for the Claude Street Filtration Plant and Landry Street Pumphouse. This equipment was purchase for a total cost of approximately $2,000, and was assumed by the MOE. The two dosing pumps required for the injection of ammonium sulphate were already available at the pumphouses.

The additional operating cost related to dosing ammonium sulphate could not be estimated accurately since the exact dosage required was not known. However, it is estimated that the additional chemical cost will be small and is well justified considering the benefit of reducing THMs levels in the distribution system.

GLOSSARY AND LIST OF ABBREVIATIONS

Alum	: aluminum sulphate
CT	: Value required to achieve adequate inactivation and/or removal of cysts and viruses. T is the time (in minutes) it takes the water during peak hourly flow, to move between the point of disinfectant and a point where C, the residual disinfectant concentration (mg/L), is measured prior to the first customer.
d	: day
°C	: degree Celsius
DWSP	: Drinking Water Surveillance Program
ECR reagent	: Eriochrome Cyanine R
FID	: Flame Ionization Detector
ft	: foot
G	: flocculation energy gradient
Gt	: flocculation energy
GC/MS	: Gas Chromatograph / Mass Spectrometry
GAC	: Granular Activated Carbon
g	: gram
h	: hour
HFS	: hydroxylated ferric sulphate (Ferriclear)
ICP	: Inductively Coupled Plasma Atomic Emission Spectoscopy
IG	: imperial gallon
kW	: kilowatt
L	: litre
L/cap.d	: litres per capita per day
L/s	: litres per second
m	: metre
m^2	: square metres
m^3	: cubic metres

m^3/d	: cubic metres per day
m/h	: metres per hour (equivalent $m^3/m^2.h$ - filtration rate)
µg/L	: micrograms per litre
mg/L	: milligrams per litre
mm	: millimetre
mL/min	: millilitres per minute
min	: minute
NTU	: Nephelometric Turbidity Unit
OCWA	: Ontario Clean Water Agency
ODWO	: Ontario Drinking Water Objective
%	: percent
PACL	: polyaluminum chloride
PVC	: polyvinyl chloride
lb	: pound
rpm	: revolution per minute
SOR	: Surface Overflow Rate
SWTR	: Surface Water Treatment Rule
T_{10}/T	: This factor describes the baffling condition in the clearwell, and represents the ratio between T_{10}, which is the time it takes 10 percent of a dye or tracer to be detected at the basin outlet after it is injected into the basin influent flow, and the theoretical detention time for plug flow in pipelines and flow in a completely mixed chamber.
TOC	: Total Organic Carbon
THMs	: Trihalomethanes
TCU	: True Colour Unit
W/V	: weight/volume

REFERENCES

American Water Works Association Research Foundation - Optimizing Chloramine Treatment, 1993.

Environmental Science and Engineering Magazine. Drinking water Update - The Facts About Human Health and Aluminum in Drinking Water, January, 1997.

APPENDICES

Temporary C of A for Chloramination System

Appendix A

NOTICE

Township of Clarence
415 Lemay Street
Clarence Creek, Ontario
K0A 1N0

You are hereby notified that the Certificate of Approval No. 7-0669-79-006, issued on July 23, 1979 for the construction of improvements to the water supply and distribution system serving the community of Clarence Creek in the Township of Clarence, as amended by a letter dated August 17, 1979, is hereby further amended to approve temporary modifications to the approved and now existing works, as follows:

- experimental installation of trihalomethane (THM) generation control chemical application systems utilizing ammonium sulphate solution to achieve water disinfection through chloramination in place of the existing chlorination, as follows:
    - installation of a 200 litre capacity solution storage tank, and one (1) positive displacement chemical metering pump rated at 10 L/hr, with a solution line to the well pump header immediately up-stream of the existing sodium hypochlorite solution application point in the well pumphouse serving Wells No. 1, 3 and 4; and
    - installation of a 200 litre capacity solution storage tank, and one (1) positive displacement chemical metering pump rated at 10 L/hr, with a solution line to the coagulation/sedimentation compartment of the existing package water treatment unit (down-stream of the existing sodium hypochlorite solution application point located in the mix compartment of the unit) in the well pumphouse serving Well No. 2;

all in accordance with the application for approval dated March 24, 1997.

Terms and Conditions

1. This Notice shall expire, and become null and void, on September 1, 1998.

Reasons for Terms and Condition

1. Condition 1 has been included to ensure that the proposed equipment is installed and used for the purpose of the proposed experiment and will not become a permanent part of the system unless so approved by the Director.

This Notice shall constitute part of the approval issued under Certificate of Approval No. 7-0669-79-006 dated July 23, 1979.

In accordance with Section 100 of the Ontario Water Resources Act, R.S.O. 1990, Chapter 0.40, as amended, you may by written notice served upon me and the Environmental Appeal Board within 15 days after receipt of this Notice, require a hearing by the Board. Section 101 of the Ontario Water Resources Act, provides that the Notice requiring the hearing shall state:

1. The portions of the approval or each term or condition in the approval in respect of which the hearing is required, and;
2. The grounds on which you intend to rely at the hearing in relation to each portion appealed.

The Notice should also include:

3. The name of the appellant;
4. The address of the appellant;
5. The Certificate of Approval number;
6. The date of the Certificate of Approval;
7. The name of the Director;
8. The municipality within which the sewage works are located;

And the Notice should be signed and dated by the appellant.

This Notice must be served upon:

The Secretary,
Environmental Appeal Board,
112 St. Clair Avenue West,
Suite 502,
Toronto, Ontario.
M4V 1N3

AND

The Director,
Section 52, *Ontario Water Resources Act*,
Ministry of Environment and Energy,
250 Davisville Avenue, 3rd Floor,
Toronto, Ontario.
M4S 1H2

The above noted water works are approved under Section 52 of the Ontario Water Resources Act.

DATED AT TORONTO this 1st *day of* August, 1997.

THIS IS A TRUE COPY OF THE ORIGINAL NOTICE MAILED
ON Aug. 11/97
SIGNED

M. Dhalla, P.Eng.,
Director,
Section 52,
Ontario Water Resources Act.

MT/ba

cc: -District Manager, MOEE Kingston District Office
-Dr. T. Edmonds, MOEE Standards Development Branch (Plant Optimization)

Operating Procedures

Appendix B

Operating Procedures – Clarence Creek Water Supply System

B.1 Chlorine Level Checks

Water samples must be taken at the Landry and the Claude streets pumphouses to measure the free chlorine residual after the sodium hypochlorite injection point, and the free and total chlorine residuals leaving the pumphouses for the distribution system.

When sampling, make sure the sample bottle is glass and is completely filled with no air space under the cover. Allow the sample to stand for 30 minutes and then measure total and free chlorine using the DPD procedure with the DR7OO analyzer.

B.2 Ammonium Sulphate Feed

The Clarence Creek groundwater supply system has a relatively high THMs formation potential. In the presence of free chlorine, THMs will be formed from the natural organics in the water leading to THMs exceeding the health objective level of 100 μg/L. Performing chloramination of the treated water leaving the pumphouses will stop any further THMs formation in the distribution system.

The procedure for determining the dosage of ammonium sulphate needed is as follows:

- Check free chlorine residual immediately after injection of sodium hypochlorite for both locations.
- Adjust chlorine feed to give a free chlorine residual of 2 mg/L.
- Add ammonium sulphate to obtain a combine chlorine residual of 2 mg/L.
- Enough ammonia solution should be made up for 7 days supply.
- Eighty-six percent (86%) of the weight of free chlorine used in one week production must be added as ammonium sulphate to the water for exact balancing. A 20% extra is suggested. Do not add more than a 20% excess of ammonia since this will encourage nitrifying bacteria in the distribution system to multiply and grow.
- Dissolve the calculated amount of ammonium sulphate (food grade) in the day tank containing 200 L of water.
- Adjust the ammonia solution pumps using a pump calibration tube to add this amount of solution over one week of projected high lift pumps operating hours.